Aug. 18, 1959 W. L. KERLIE 2,900,249

SURFACE BLOWING PROCESS FOR MAKING STEEL

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FIG. 1.

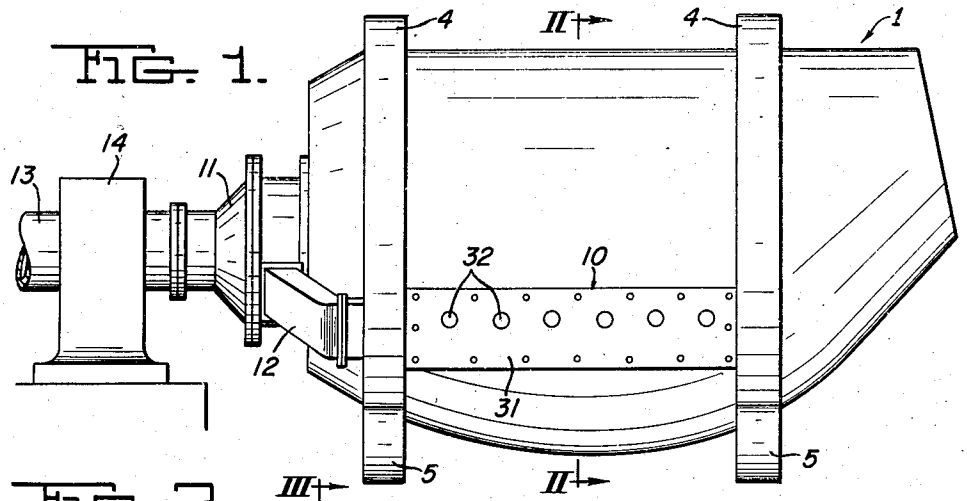


FIG. 2.

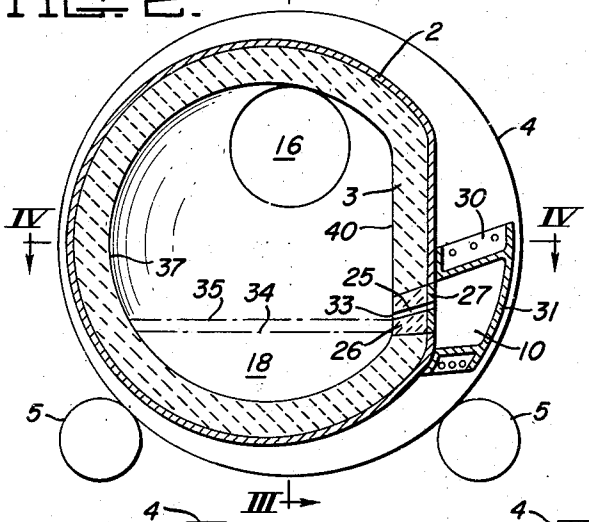
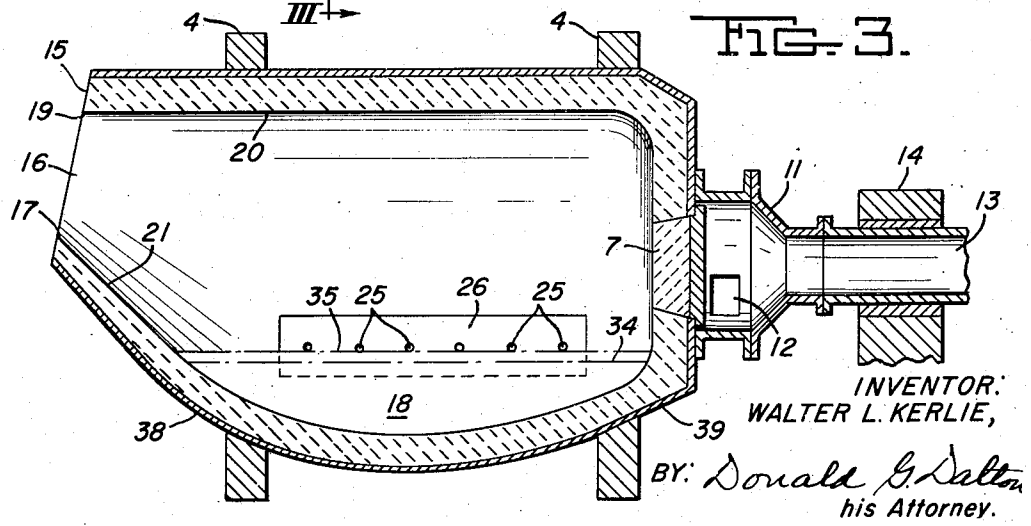


FIG. 3.



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FIG. 4.

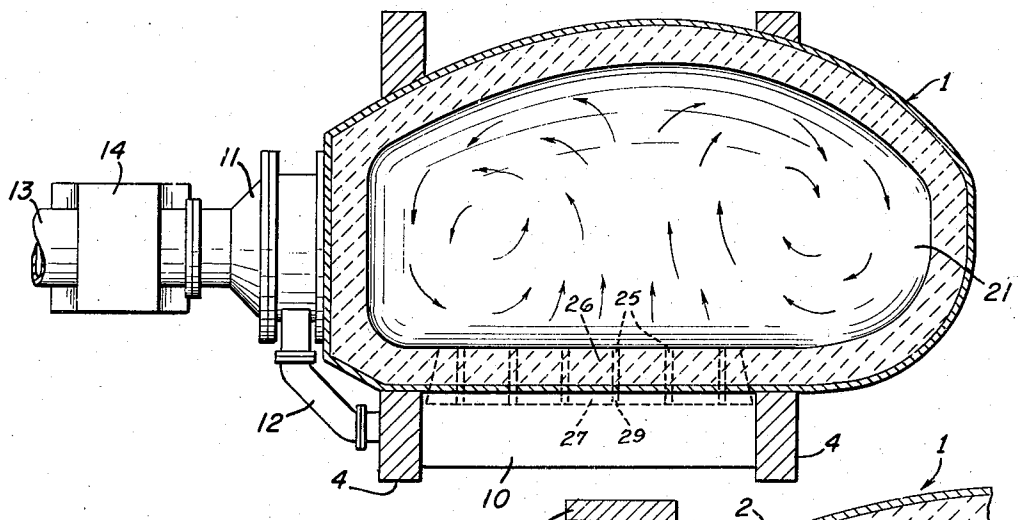
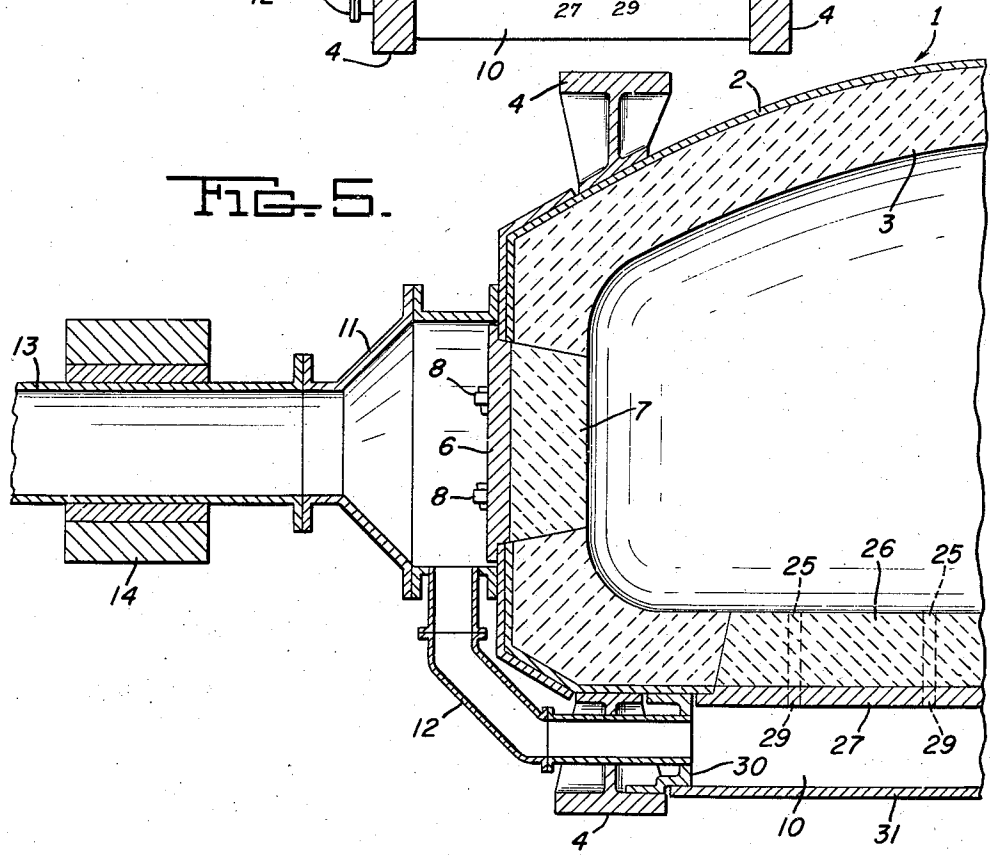


FIG. 5.



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SURFACE BLOWING PROCESS FOR MAKING STEEL

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Application June 1, 1956, Serial No. 588,762

6 Claims. (Cl. 75—60)

This invention relates to a pneumatic process for refining pig iron which utilizes surface blowing as distinguished from submerged blowing wherein the blast is introduced below the surface of the metal as in bottom-blown and side-blown conventional Bessemer converter practices. More particularly, it relates to the surface blowing process disclosed in United States Patent No. 2,733,141 to Clarence E. Sims and is concerned with improvements in such process which are directed to the end of obtaining a more efficient refining operation and to the solution of incidental problems which determine the practicability of the process. Among other features, the process of this invention reduces iron losses and increases the life of the converter refractory lining by controlling the circulating movement of the slag over the molten metal and by causing the gases to flow spirally through the converter.

Prior to development of the surface blowing process disclosed in the above mentioned Sims patent, pneumatic processes for refining steel were universally regarded in the steel industry as being unsuitable for making deep drawing low carbon steels and as having restricted application to certain types of pig iron. With respect to pig iron composition, the acid Bessemer process requires a pig iron high in silicon (1.0% min.) and low in phosphorus (0.10% max.), and the basic Bessemer process requires a pig iron with a silicon content less than 1.0% and high in phosphorus (1.8% min.). Low carbon steels having good deep drawing characteristics cannot be produced by these processes because the blow required for lowering the carbon content results in excessive absorption of nitrogen. As a consequence, the slower and more expensive open hearth practice has been considered essential for making steels which are low in carbon, phosphorus and nitrogen as well as for refining American basic pig iron which has a phosphorus content in the range of 0.15% to 0.5% and is thus unsuitable for Bessemer operations.

Contrary to these viewpoints, the Sims process proposes to refine American basic pig iron and to produce steel which is low in carbon, phosphorus and nitrogen by a pneumatic surface blowing operation. As disclosed and explained in the above mentioned patent, it is essential to this process that a rolling state of agitation of the slag on the surface of the metal be produced by the air blast. For this purpose, the patent specifies among other requirements a blast delivering air at a low angle of incidence against the surface of the bath, at a velocity of 300 to 500 feet per second, and at a rate which will remove about 0.5 carbon per minute, to maintain the condition of slag agitation essential to a successful refining operation. The latter involves the introduction of air at rates as high as 1500 c.f.m. per ton of iron charged. Since the improvements of this invention relate to and contemplate a practice of the Sims surface blowing process, reference is accordingly made to the above mentioned United States Patent No. 2,733,141 for a more detailed description and further understanding of the features of

the process which are used in the practice of the improvements of this invention.

In general, the air required in the Sims surface blowing process enters the vessel at about room temperature and is heated almost instantaneously by the oxidation reactions it causes, to a temperature of about 2500° F. expanding to some twenty times its original volume. As a result, the different gases leave the vessel at a velocity which is conducive to iron and slag losses by ejection from the converter mouth which, in the converter shown in the above mentioned Sims patent as well as in most conventional converters, is located directly over the molten bath. In accordance with the principles of this invention, slag and iron losses of this nature and splashing tendencies are reduced by conducting the blowing operation in a converter which has its mouth located at one side of the bath and thus provides a cover over the bath. The provision of a bath cover in this manner prevents the movement of splashing slag and metal directly out of the converter mouth with the burning gas as is permitted in conventionally constructed converters. As an incident to preventing slag and iron losses by splashing in this manner, a spiral movement is imparted to the gases during movement to the converter mouth which produces an improved heat transfer to the bath by effecting more complete combustion of carbon to CO_2. This increased heat is available to melt scrap and thus increases the yield of the operation.

The Sims process further produces an extremely fluid slag which, in view of the blast velocities required to maintain it in the rolling state of agitation essential to this process and the enormous increase in gas volume which occurs adjacent to the discharge ends of the tuyeres, results in a surging condition of the slag cover on the bath. This surging condition causes damage to the refractory lining of the converter vessel, the tuyere blocks in particular, when conducted in a vessel of the conventional design shown in the said patent. As shown in the patent, the blast is applied to the surface of the bath at a low angle of incidence from one side of the vessel and, in practice, this has been found to throw a surging non-circulating wall of slag against the other side of the vessel which in rolling back toward the tuyeres envelops the blast and is violently hurled by the expanding gases against the refractory lining. The resulting eroding or wearing action on the vessel lining is particularly bad in the tuyere wall area since it cuts this wall unevenly and rapidly increases the distance of the tuyeres from the bath. The latter is conducive to surging and the wear thus proceeds at an increased rate. The improvements of this invention eliminate this condition by giving the bath a particular shape and projecting the blast against its surface in such manner that the slag and metal at the surface of the bath are circulated continuously without surging or roll back action and damage to the vessel lining. In addition, this slag circulating action produces among other advantages a faster rate of solution of the lime and develops a homogeneous slag early in the heat so that the end point of the heat is reached rapidly and without uncertainty.

To the above and related ends, the refining process of this invention is preferably conducted in a cylindrical or barrel-shaped converter vessel which is mounted for rotation about a horizontal axis and has rounded ends and a mouth or nose portion opening out of one of such ends. The provision of a vessel of this shape enables a more shallow bath to be had with a greater tuyere blast area per ton of metal. The vessel shape and tuyere blast cooperate to provide the continuous circulating movement of the slag over the surface of the metal.

Further details and advantages of the invention will become apparent from the following description. In the

drawings, there is shown a preferred form of apparatus for practicing the improved process of this invention. In this showing:

Figure 1 is a side elevation of a converter which is particularly adapted to the practice of the process of this invention;

Figure 2 is a vertical sectional view taken substantially in the plane of the line II—II of Figure 1;

Figure 3 is a sectional view taken substantially in the plane of the line III—III of Figure 2;

Figure 4 is a sectional view taken substantially in the plane of the line IV—IV of Figure 2; and

Figure 5 is an enlarged and detailed sectional view of one end of the converter vessel which shows its connection to an air blast coupling.

As stated above, the practice of the process of this invention is effected in a converter vessel which has its mouth or nose positioned at one side of the bath and thus provides a cover over the bath. A preferred form of vessel for this purpose is designated as a whole by the numeral **1** in the drawings which show it as having a cylindrical or barrel shape. It has a metal shell **2** with a refractory lining **3** in the manner of conventionally fabricated converters and is mounted for rotation with its axis in a horizontal position. Its mounting includes a pair of axially spaced rocker rails or wheels **4** which are secured to the shell **2** concentrically with respect to the axis of the vessel **1** and have rolling engagement on supporting rollers **5**. A sprocket or gear drive (not shown) is provided for tilting the vessel **1** to and from its upright blowing position as shown in the drawings.

As best shown in Figure 5, the inner end of the vessel **1** is closed by a manhole cover which includes a mounting plate **6** and a prerammed and tapered dolomite block **7**. Wedge and cotter assemblies **8** secure the plate **6** to the shell **2** as in the standard basic Bessemer converter. The provision of a removable manhole in this manner enables replacement of the refractory lining **3** according to the practice used in relining standard basic Bessemer converters. For relining in this manner, the manhole **6** is removed and the vessel **1** is placed in an upright position after removal from its supporting rollers **5**. After the lining **3** has been replaced, a tapered block **7** is rammed into position and the wedging cotters **8** are operated to secure the plate **6** to the shell **2**.

A wind box **10** extends between the rocker wheels **4** and is supplied with air from a coupling **11** which is connected with the wind box **10** by a conduit **12**. The coupling **11** is removably secured to the shell **2** about the manhole plate **6** and is connected to an air supply conduit **13** which is rotatably supported in a bearing **14**.

At its outer end the converter has a nose section **15** which is shaped to provide a mouth **16** in a skewed and eccentric position with respect to the axis of the converter as best shown in Figure 3. When the vessel is in its operative blowing position as shown in the drawings, its mouth **16** is arranged at one side of the area directly over the bath and faces outwardly in an endwise direction from the vessel. The mouth **16** has its lower edge **17** located well above the surface **18** of the converter bath and its upper edge **19** is flush with the top **20** of the lining which provides a cover over the bath. From the lower edge **17**, the lining surface **21** slopes downwardly at an angle of approximately 45°. The shape of the nose **15** and the skewed location of the mouth **16** are effective in preventing ejection of metal and slag from the vessel by splashing. To tap slag or metal it is only necessary to rotate the vessel in a counter-clockwise direction as viewed in Figure 2 to lower the mouth **16** to a position below the level of a bath in the converter. The mouth **16** preferably has a large diameter providing for visual inspection of the lining and such fettling repairs thereto as may be needed. The provision of a wide mouth **16** in a relatively short nose section **15** results in a relatively low velocity of the spirally moving waste gas emerging from the vessel. In this manner, deposition of slag and metal in the upper portion of the nose **15** is kept at a minimum and skulling of the mouth **16** is eliminated.

The wind box **10** mentioned above delivers air to a plurality of tuyeres **25** in a preformed refractory block **26** which is rammed in an opening in the lining **3** as best shown in Figure 2. The tuyeres **25** are parallel and extend transversely of the vessel axis so that the gases have a spiral motion in moving to the mouth **16**. The block **26** is held in position by a bottom plate **27** secured to the shell **2**. The plate **27** has openings **29** through which air is delivered from the wind box **10** to the tuyeres **25**. Upper and lower edges of the box **10** are formed by side plates **30** which are bolted to the shell **2** and at their ends to the rocker rails **4**. A cover plate **31** completes the enclosure for the wind box **10** and is provided with sight openings **32** so that furnace conditions may be observed by sighting down the tuyeres **25**.

Figure 2 shows the angular positions of the tuyeres **25** when the converter is in an operative blowing position. In this position, the lower ends **33** of the tuyeres **25** are positioned above (one to seven inches in practice) the surface **34** of the metal and preferably slightly above the surface **35** of the slag, which surfaces are designated by the broken lines in Figures 2 and 3. The axes of the tuyeres **25** respectively form a flat angle of incidence with the surface of the metal which should be kept between 10 and 20°. For best surface blowing conditions, this angle should be about 15°. The tuyere axes intersect with a vertical plane through the center of the mouth **16** at an angle of less than 90° and which is 75° for the preferred tuyere angle of 15°.

As shown in Figure 2, the main body of the vessel **1** is eccentrically disposed with respect to the rocker wheels **4** so that, for any given size of unit, the maximum distance between the tuyeres **25** and the opposite wall **37** of the lining **3** obtains. In this way erosion of the wall **37** opposite the tuyeres is reduced to a minimum. Furthermore, the thickness of the opposite wall **37** can be increased, if necessary, to match the wear on other parts of the vessel lining and, consequently, to improve the overall lining life of the vessel. The eccentric disposition of the vessel **1** with respect to the rocker wheels **4** further permits the use of a relatively large diameter vessel and still leaves sufficient space for the blast box **10** within the perimeters of the rocker wheels **4**.

The main body of the vessel **1** has a curved or barrel shape as shown in Figure 3 and has its ends rounded in the regions **38** and **39** (see Figure 3). In addition, the side wall of the vessel is flattened in the region **40** (see Figure 2) above the tuyere block **26** so that the bath contained in the vessel will have a substantially D-shaped surface contour with the tuyeres **25** arranged along the flat side of the D-shape. In operation the air blast from the tuyeres **25** moves the slag across the surface of the metal toward the opposite wall **37**. However, and by reason of the curvature of the wall **37** in a horizontal plane, the slag will not build up against such wall but will circulate continuously in two distinct zones, one at each end of the vessel, over the surface of the metal as indicated by the arrows in Figure 4. This circulating movement of the slag gives rise to more intimate mixing with the metal as well as a more rapid fluxing of the slag forming materials because the FeO formed by the action of the blast on the metal is immediately swept into the slag by the spiralling movement of the waste gases. The rapid fluxing of the slag and the intimate mixing of slag and metal results in a fast oxidation rate and develops a homogeneous slag at an early stage in the blow. Consequently the end point of the heat is reached quickly and without any uncertainty. Uncertainty about the end point leads to repeated blowing for brief periods toward the end of the heat or to prolonged blowing times.

A cylindrical or barrel-shaped vessel **1** arranged with

its axis horizontal and mounted for rotation about such axis is preferred for the reason that it provides a more shallow bath which gives a greater tuyere area per ton of metal in addition to providing for circulation of the slag over the surface of the metal. In addition, the arrangement of the vessel **1** on its side with its mouth **16** at one end provides a cover over the entire surface of the bath. This further reduces losses by splashing and spraying which are otherwise apt to take place in a converter having its mouth open to the atmosphere in an area directly over the bath.

The gases produced by the blast from the tuyeres **25** adopt a spiral motion in moving toward the mouth **16**. This spiral motion is the result of a rotational movement caused by the curvature of the wall **37** opposite the tuyeres **25** and the axial movement of the gases toward the mouth **16**. The spiral movement results in a better mixing of the gases and more complete combustion of carbon to carbon dioxide within the vessel and an improved heat transfer to the bath. This gives rise to additional heat sufficient to melt an appreciable quantity of scrap and increases the production of the converter.

From the standpoint of reducing splashing, improved slag circulation with respect to elimination of the surging slag wall mentioned above, and imparting a spiral motion to the burning gases, best results are obtained when the spacing between adjacent tuyeres **25** is maintained within limits determined by the tuyere diameters and the wind velocity in the tuyeres. The minimum tuyere spacing is given by the empirical equation

$$S=2.5\ D^2V^2/10^6$$

wherein S is the tuyere spacing in inches, D is the tuyere diameter in inches, and V is the wind velocity in feet per second. It has also been found that there is little advantage in making the tuyere spacing greater than $3.0\ D^2V^2/10^6$ inches. For example, with five 5-inch tuyeres and a wind velocity of 500 feet per second, the tuyere spacing should be between 16 and 19 inches; with three 6½-inch tuyeres and the same wind velocity, the tuyere spacing should be between 26 and 32 inches.

To obtain most effective slag circulation, the axial length of the side-circulation zones (as measured by the distance between the center line of the outer tuyeres and the ends of the bath) should be 27+S/2 inches to achieve an adequate return circulation and thereby an adequate mixing of metal and slag-forming constituents. For example, with five 5-inch tuyeres and a wind velocity of 500 feet per second, the width of each side-circulation zone should be at least 35 inches, and the length of the bath should be at least 134 inches. The spacing of the outer tuyeres from the ends of the bath results in the application of the blast to an area centrally of the bath so that the slag is circulated over the circular paths as designated by the arrows in Figure 4.

In operation of the converter, the lime required for a charge is added to the vessel which is then rotated to place the tuyere ends **33** above the expected level of the bath. After charging molten pig iron by pouring through the mouth **16**, the vessel is rotated to lower the tuyeres to their blowing position. The blast is then turned on and the blowing proceeds. Attention is particularly directed to the fact that the cylindrical shape and horizontal position of the vessel **1** provides a cover over the bath during blowing. Since the tuyeres **25** project the blast against the surface of the bath in a direction transversely of the vessel axis, splashing slag and metal is not carried out of the vessel but is projected against the bath cover provided thereby. This transverse direction of blast relative to the axis of the vessel together with the curvature of the vessel wall **37** and the arrangement of the mouth **16** at one end of the vessel cause a spiral movement of the gases to the mouth **16** as explained above. Attention is further directed to the fact that this transverse direction of blast in cooperation with the shape of the bath is effective in circulating the slag and metal over the surface of the bath for the reasons mentioned above.

While one embodiment of my invention has been shown and described it will be apparent that other adaptations and modifications may be made without departing from the scope of the following claims.

I claim:

1. A pneumatic process for refining iron which comprises charging a bath of molten iron and slag in a converter, projecting an oxidizing blast at a low angle of incidence against the surface of said bath in a direction across an area of said surface arranged centrally between surface areas at the ends thereof, utilizing said blast to move slag over said central area, and circulating the slag in opposite rotational directions over the said end areas of said bath to return it into the path of said blast.

2. A pneumatic process for refining iron in an elongated converter which comprises supporting said converter in a horizontal position, charging a bath of molten iron and slag in the lower portion of said converter, projecting an oxidizing blast at a low angle of incidence against the surface of said bath in a direction transversely of said converter and across an area of said surface arranged centrally between surface areas at the ends thereof, utilizing said blast to move slag continuously over said central area, and circulating the slag in opposite rotational directions over the said end areas of said bath to return it into the path of said blast.

3. The pneumatic process defined in claim 2 characterized by projecting said blast from a plurality of tuyeres arranged at spaced intervals along and extending radially through a side portion of said converter opposite said bath central area.

4. A pneumatic process for refining iron in a converter having a gas discharge mouth at one end thereof which comprises supporting said converter in a horizontal position with its said gas discharge mouth opening outwardly therefrom, charging a bath of molten iron and slag in the lower portion of said converter, projecting an oxidizing blast at a low angle of incidence against the surface of said bath in a direction transversely of said converter and across an area of said surface arranged centrally between surface areas at the ends thereof, utilizing said blast to move slag continuously over said central area, circulating the slag in opposite rotational directions over the said end areas of said bath to return it into the path of said blast, and moving the gases produced by said blast with a spiral motion over the surface of said bath to said converter gas discharge mouth.

5. In a pneumatic process for refining iron in a converter the lower portion of which has a D-shaped contour in a horizontal plane, the steps which comprise charging a bath of molten iron and slag in said lower portion, projecting an oxidizing blast at a low angle of incidence against the surface of said bath in a direction from the flat side of the converter toward the curved side thereof and across an area of said surface arranged centrally between surface areas at the ends thereof, utilizing said blast to move slag continuously over said central area, and circulating the slag in opposite rotational directions over the ends of said curved side and the said end areas of said bath to return it into the path of said blast.

6. In a pneumatic process for refining iron in a converter supported in a horizontal position with its mouth opening axially outwardly from one end thereof, said converter having a barrel shape with a flattened portion along one side thereof such that its lower portion has a D-shaped contour in a horizontal plane, the steps which comprise charging a bath of molten iron and slag in said lower portion, projecting an oxidizing blast at a low angle of incidence against the surface of said bath in

a direction from the flat side of the converter toward the curved side thereof and across an area of said surface arranged centrally between surface areas at the ends thereof, utilizing said blast to move slag continuously over said central area, circulating the slag in opposite rotational directions over the ends of said curved side and the said end areas of said bath to return it into the path of the blast across said central area, and moving the gases produced by said blast with a spiral motion over the surface of the bath to said converter mouth.

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